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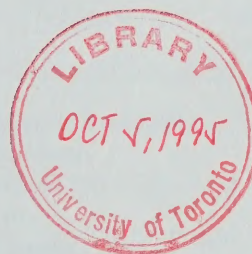
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Current Issue Review

79-37E

ACID RAIN



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Science and Technology Division

28 November 1979
Reviewed 23 March 1995



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Canada Communication Group -- Publishing
Ottawa, Canada K1A 0S9

Catalogue No. YM32-1/79-37-1995-05E
ISBN 0-660-16099-4

N.B. Any substantive changes in this publication which have been made since the preceding issue are indicated in **bold print**.

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ACID RAIN

ISSUE DEFINITION

Although it is no longer at the forefront of environmental issues, acidic precipitation, or acid rain as it is commonly called, remains a subject of concern to many Canadians. When the acidification of lakes was first described in Ontario in the early 1950s, the phenomenon was considered to be simply a local problem resulting from the lakes' proximity to nickel smelting operations in and around Sudbury. Since then, however, scientists have documented the acidification and the demise of numerous additional lakes; acidification is now acknowledged to be widespread and a major environmental problem.

Acidic precipitation is derived principally from emissions of sulphur and nitrogen oxides which are released to the environment during the combustion of fossil fuels and the smelting of sulphide ores. As the pollutants are transported for hundreds, or perhaps thousands, of kilometres through the atmosphere, the oxides enter into a complex series of chemical reactions to form acids. Sulphuric and nitric acids are the most frequently found types.

Freshwater ecosystems are most vulnerable to the harmful effects of acidic precipitation but damage can be inflicted on man-made structures and artifacts as well. The effects of acidic precipitation on terrestrial ecosystems, including agricultural crops and forests, are not well-defined although most authorities agree that a potential for damage exists. Recently, scientists have become concerned about the relationship between acid deposition, in combination with other air pollutants, and forest damage in Europe and Eastern North America.

Although acid rain is not believed to pose a direct risk to human health, there is evidence that the inhalation of acid aerosols can irritate the respiratory tract and aggravate respiratory ailments. The issue is made more complicated, however, by the fact that the effects



of acidic pollutants may be difficult to separate from those of other atmospheric pollutants such as ground-level ozone. Human health may also be harmed indirectly by elevated levels of toxic metals in drinking water and food which can occur as a result of acid deposition.

BACKGROUND AND ANALYSIS

A. Historical Perspective

Acid rain is not a new phenomenon although public awareness of the problem is a more recent development. In the mid-seventeenth century, Evelyn (in 1661) and Gaunt (in 1662) noted the influence of industrial emissions on the health of plants and people and the transboundary exchange of pollutants between England and France. They suggested remedial measures including the placement of industry outside of towns and the use of taller chimneys to spread the "smoke" into "distant parts." In 1872, Smith, in a pioneering publication entitled "Air and Rain: The Beginnings of a Chemical Climatology", first used the term "acid rain" and described many of the concepts we now consider part of the acidic precipitation problem.

Current awareness of the scope of the acid rain problem has its origins in observations, made in Scandinavia in the 1950s and 1960s, of the increasing acidity of rainfall and of instances of decreasing fish populations. The Scandinavian observations prompted an OECD program to extend measurements over a wider area of Europe. The program, which ran from 1972 to 1977, confirmed the long-range transport of sulphur compounds and pointed to the need for international cooperation to combat the problem.

In Canada, abnormal acidity in precipitation and in Nova Scotia lakes was detected in the mid-1950s. It was hypothesized that the acidity was due to airborne pollution from distant sources. In the mid-1960s, losses of fish populations in lakes southwest of Sudbury, Ontario, were attributed to acidification caused by acid rain.

In 1978, in response to mutual interests and concerns, the Governments of the United States and Canada established a United States-Canada Research Consultation Group to study the problem of the long-range transport of air pollutants (LRTAP). This Group was to study LRTAP and the related phenomenon of acidic precipitation and to aid in the coordination of research studies and the exchange of scientific information between the two countries. A

preliminary report released by Environment Canada in October 1979 "identified acidic precipitation as the problem of greatest common concern at the present time." On 5 August 1980, Canada and the United States signed a "Memorandum of Intent Concerning Transboundary Air Pollution" as a preliminary step in the development of a bilateral agreement on air quality which would deal effectively with such pollution and, at the same time, combat acidic precipitation.

As concern mounted over the widespread damage caused by acid rain, major initiatives to decrease acid rain-causing emissions were introduced. In July 1985, 21 countries including Canada signed the Helsinki Protocol, which called for a 30% reduction of SO₂ emissions from 1980 levels as soon as possible and at the latest by 1993. The Canadian Acid Rain Control Program was introduced in the same year. Its objective was to reduce SO₂ emissions in eastern Canada by 50% from the 1980 level of 4.6 million tonnes.

Progress in the United States has been somewhat slower, but in 1990 the United States brought in the very comprehensive *Clean Air Act Amendments*. Title IV of the Amendments will cut SO₂ emissions by 9.1 million tonnes by the year 2000.

On 13 March 1991, Canada and the United States signed a bilateral Air Quality Agreement which commits both countries to specific schedules for the reductions of acid-forming emissions. The significance of the Agreement is much broader than acid rain in that it establishes a framework for dealing with other transboundary air pollution problems.

B. Formation of Acid Rain

Natural unpolluted rain is not pure water; it is a dilute solution of carbonic acid, which forms when atmospheric carbon dioxide dissolves in water. This acid dissociates in water to release only enough H⁺ ions to lower the pH of precipitation from 7 to about 5.6; thus, the acidic precipitation which arises from man's pollution of the atmosphere has a pH below 5.6. (A pH of 7 represents neutrality. Each unit decrease of pH corresponds to a ten-fold increase in acidity.)

Acid rain is formed when pollutant compounds, primarily the oxides of sulphur and nitrogen, react with oxygen and moisture in complex reactions in the atmosphere to form

acids. Although the details of the chemical reactions which take place in the atmosphere are not completely understood, some of the oxides of sulphur and nitrogen are converted to sulphuric and nitric acids, respectively. These are strong acids and they dissociate completely in water releasing hydrogen ions to solution; thus, they can lower the pH of precipitation significantly. One of the most acidic rainfalls yet recorded fell in Scotland in 1974 and was measured at 2.4 on the pH scale -- roughly the pH of vinegar (dilute acetic acid) and over one thousand times as acidic as natural rain. In December 1982, a sample of fog taken at Corona del Mar in Southern California had a pH of 1.69. This extremely high acidity developed after a two-day ground-level temperature inversion in the Los Angeles basin which prevented air pollution from dispersing.

C. Emissions of Acidifying Pollutants in North America

The most important acidifying air pollutants are sulphur dioxide (SO_2) and nitrogen oxides (NO_x). The most comprehensive information on emissions of SO_2 and NO_x now available is for the base year 1980, although there is also some information on emissions in more recent years. The emissions inventories for SO_2 and NO_x in North America are not precise, but the errors are estimated to be less than 10% on a national basis.

1. Sources of Emissions

In 1980, Canadian emissions of SO_2 totalled some 4.6 million tonnes, with slightly less than 50% coming from the non-ferrous smelting sector. Emissions of SO_2 in the United States amounted to 24 million tonnes; thermal power generation contributed about two-thirds of this total. On a per-capita basis, Canada produces about twice as much SO_2 as does the United States. SO_2 emissions in both countries have a strong regional character: about 80% of total emissions come from provinces east of the Manitoba-Saskatchewan border and from the 31 states east of the Mississippi River in the U.S.A.

Emissions of NO_x in 1980 are estimated to have been 21 and 1.7 million tonnes in the United States and Canada, respectively. In both countries, the transportation sector and electric power generation are the largest contributors, the latter being particularly significant in the U.S.A. Emissions of NO_x are more uniformly distributed than those of SO_2 , but more than

60% of emissions are contributed by the eastern regions. On a per-capita basis, the United States produces more NO_x than does Canada.

The acid-forming potential of SO_2 emissions in eastern North America is approximately twice that of NO_x emissions. Natural (versus anthropogenic) emissions of SO_2 and NO_x probably contribute to the acid rain phenomenon, but this contribution is small in eastern North America compared to the quantities of anthropogenic emissions. Although emissions of NO_x contribute to the acidity of precipitation, NO_x is not a major cause of acidification of surface waters in eastern Canada.

2. Seasonal Variation

The seasonal variation in emissions is fairly small and is estimated to be less than $\pm 10\%$ from the national average. In some areas of Canada, however, the phenomenon of "acid shock" is important in the spring of the year. This occurs when acidifying pollutants, particularly NO_x , accumulate in the snow pack and are released in a short period of time during snow-melt.

3. Historical Trends

Over the past 30 years, there has been considerable fluctuation in SO_2 and NO_x emissions in North America. Emissions of SO_2 peaked in the late 1960s and early 1970s in both countries and have dropped since. Recent estimates indicate an accelerated decline in SO_2 emissions from 1979 to 1982, partly due to the economic downturn. There may have been a slight increase in 1983, coincident with the economic recovery. NO_x emissions in Canada and the U.S.A. have increased greatly since the 1950s, from 9 to 21 million tonnes in the U.S.A. and from 0.6 to 1.7 million tonnes in Canada.

The characteristics of emission sources have also changed. Most noteworthy has been the progressive increase in the proportion of SO_2 released from tall stacks. This has enhanced the potential for long-range transport of this pollutant.

D. Acid Deposition

Deposition patterns and loadings (the amount of pollutant deposited on a unit area) are important considerations in the acid rain scenario. During the preparation, several years ago, of the Memorandum of Intent Work Group Reports, the target loading of 20 kilograms per hectare per year (20 kg/ha/yr) of wet sulphate in precipitation was proposed as a level that would provide protection for the aquatic environment, except for the most acid-sensitive lakes and rivers. These most sensitive aquatic ecosystems may not be protected if total (wet plus dry) sulphate deposition exceeds 12 kg/ha/yr.

In recent years, southern and central Ontario and Quebec have had a wet sulphate loading in excess of 20 kg/ha/yr, as has most of the United States east of the Mississippi Valley. In Canada's Atlantic Provinces, the wet deposition rate is close to the 20 kg mark and is slightly exceeded in some places in some years. In western Canada, loading appears to be below 20 kg/ha/yr and the same is true for the United States.

Between 1980-82 and 1985-87, the area of North America receiving loadings of wet sulphate in excess of 20 kg/ha/yr shrank significantly; however, nitrate loadings did not change significantly over the same period.

E. Environmental Effects of Acid Rain

More is known about the effects of acid rain on some sectors of the environment than on others. A good deal is known about the effects of acidification on aquatic ecosystems but much less is known about the effects on terrestrial ecosystems, agricultural crops, or human health.

1. Aquatic Ecosystems

Aquatic organisms vary greatly in their ability to tolerate fluctuations in the acidity of their environment. Some species are very sensitive to acidification and, as the pH of lakes, rivers and groundwaters decreases, the least-tolerant species disappear first, followed by less sensitive species as the pH continues to drop. In southern Norway and Sweden, for example, the acidification of lakes has resulted in the decline of various species of fish, with trout and

salmon being amongst the first to disappear. In Ontario, a well-documented sequence of decline follows the order: lake trout, brook trout and walleye, with perch being one of the more resistant species.

With reference to specific effects of pH, mortality of lake trout and brook trout alevins incubated in containers of gravel (pH 5.5) was significantly higher than of those incubated in limestone materials (pH greater than 6.0). Similarly, mortality of Atlantic salmon fry in limestone-treated water (pH 6.1) was significantly lower than mortality of fry in untreated water (pH 5.0). Moreover, studies have shown that the number and diversity of fish species decrease in lakes when the pH drops below 6.0.

Organisms other than fish are affected by acidification. Algal communities become less diverse in lakes as the pH drops below 6.0. The survival of rooted plants is generally diminished in acidified lakes and, conversely, the growth of benthic (bottom-growing) mosses and attached algae is usually enhanced. As the pH falls, the number of invertebrates in the water column and in the sediments decreases, the rate of decomposition of organic matter decreases, and fungi begin to replace bacteria as the dominant decomposer organisms. These developments can lead to a reduction in nutrient cycling in a lake, and this in turn can result in reduced productivity.

The loss of species from an ecosystem reduces the diversity of that ecosystem and may make the whole community progressively more unstable. Thus, even if a species happens to be acid-resistant, it may nevertheless be doomed to extinction if its natural prey is acid-sensitive and disappears from the environment.

In some cases, acid conditions may not kill adult organisms directly but their reproduction may be affected. Furthermore, some organisms may be acid-resistant but sensitive to metal pollution. Metallic ions are generally more soluble under acidic conditions; consequently, elevated levels of metals may themselves harm some organisms, or they may act synergistically with acid conditions to bring about physiological stress and the eventual demise of susceptible species. Elevated concentrations of aluminum, manganese, zinc, cadmium, lead, mercury, copper and nickel have frequently been observed in acidified lakes although it is not yet known whether these metals originate from deposition with the acid rain or whether they are leached from sediments by the acidified waters.

Surveys have indicated that approximately 14,000 Canadian lakes are currently acidified. Computer models predict that a further 10,000 to 40,000 lakes will be acidified in eastern Canada if wet sulphate deposition in the most heavily impacted regions is not decreased.

There is presently a paucity of direct evidence of changes in aquatic ecosystems in the sensitive areas of Canada as a result of acid deposition. However, loss of Atlantic salmon populations in several rivers in southwestern Nova Scotia has been recorded and fish population losses and declines have been recorded in lakes in Ontario. Moreover, extensive fish surveys in eastern Canada have confirmed that species diversity and richness are reduced in acidified surface waters.

There is now limited information that aquatic biological communities can recover fairly quickly from acidification (in years rather than decades) once the level of acid loading is reduced. The artificial "liming" of acidified waters has had some success in decreasing acidification and re-establishing some fish populations. However, the procedure is expensive and there are problems with it because liming is not an exact reversal of the acidification process.

2. Terrestrial Ecosystems

At the present time, there is incomplete understanding of how acidic precipitation affects terrestrial ecosystems. Terrestrial ecosystems are inherently extremely complex; so many factors influence the growth and development of land-based ecosystems that it is difficult to isolate and characterize the effects of acid rain alone. Some facts are known, however. Acid rain can: damage foliage; accelerate the erosion of the waxy covering of leaves which may lead to the loss of water or which may reduce a plant's ability to resist the attack of disease-causing organisms; inhibit the germination of seeds and the growth of seedlings; decrease the respiration of organisms living in the soil, which may in turn affect the availability of some nutrients; increase the leaching of nutrient ions from the soil; and enhance the solubilization of aluminum in the soil, which can have negative effects on biological processes. On the other hand, it is not known to what extent the ill-effects listed above might be counterbalanced by the nutrient input which could be derived from the sulphur and (especially) the nitrogen compounds which are found in acidic precipitation.

Through the late 1970s and the 1980s, concern was raised over the decline of sugar maples. The phenomenon was most severe in Quebec and acid rain was suspected as a factor. Recent evidence from the North American Sugar Maple Decline Project has shown that the health of sugar maples improved between 1988 and 1990 and suggests that drought and insect defoliation, rather than acid rain, were the primary causes of the decline.

The evidence to date suggests that forest decline in several parts of the world is due, at least in part, to air pollution, including acid rain. Direct association is not possible because so many factors impact on forest ecosystems, including insects, disease, adverse weather and climate, in addition to air pollutants.

Acidic precipitation has not yet been shown to damage agricultural crops directly, but air pollution in general does inhibit the growth of some commercial species. There are two possible mechanisms by which the damage from acid rain might occur; it could damage the surface of the plants directly or it could affect the growth of crops by altering the chemistry of the soil. Repeated rainfalls with pH less than 3 would be required to produce overt crop damage of economic significance. A related issue concerns the damaging effect of ozone on sensitive agricultural crops, which is now well documented. Ozone is a major component of photochemical smog, of which nitrogen dioxide is a precursor. Thus, a reduction in NO_x emissions could have the two-fold beneficial effect of reducing both acid rain and ozone pollution.

3. Human Health

Although direct effects of acid rain on human health have yet to be unambiguously demonstrated, some health authorities feel it may be injurious to some people. The possibility that sulphate air pollution might affect human health is widely accepted by medical authorities.

Extremely small particulates, formed in the atmosphere by the oxidation of sulphur dioxide, are capable of penetrating deeply into the human respiratory system. Acidic particulates can cause chronic bronchitis or emphysema, with the resultant difficulty in breathing leading to increased strain and, possibly, eventually to heart disease. Oxides of nitrogen can suppress the action of pulmonary scavenger cells whose function it is to purify the lungs by

removing insoluble particulates. This effect could also lead to increased susceptibility to respiratory ailments.

A study in 1983, using eight years of data, showed an association between increased hospital admissions for respiratory illnesses in southwestern Ontario and increased ambient levels of sulphate, ozone, and temperature. It is assumed also that less severe respiratory illnesses also increased in number, but those were not recorded.

Another study compared the chronic health effects of exposure to air pollution in school children residing in Tillsonburg, Ontario (a high LRTAP community) and Portage La Prairie, Manitoba (a low-pollution community). The children in Tillsonburg had a small (2%) but statistically significant decrement in lung function and had a higher incidence of a number of respiratory symptoms. These findings are regarded as suggestive of the harmful effects of air pollutants, but not conclusive, and additional studies are underway to clarify the cause-and-effect relationship.

There is also a growing concern, for the first time, of acidification and possible contamination of groundwater. Domestic supplies of water are, however, generally drawn from below the water table where the groundwater, so far, shows little evidence of acidification.

Acidic water passing through plumbing may increase copper and lead concentrations in the water, and some natural spring waters from watersheds which have experienced acidification have shown elevated levels of lead, copper, aluminum, mercury and cadmium. All these metals are potentially toxic but the extent of the effects and the health costs associated with them have not yet been calculated. In some acid-sensitive regions of Ontario with poorly buffered soils, toxic metals are taken up by lichens and other plants eaten by deer and moose. The liver and kidney of these animals have been declared unfit for human consumption in certain areas because of their high cadmium content. Asbestos contamination of drinking water is of some concern in areas where acidified water is collected in cisterns using asbestos-cement roofing tiles as catchments.

Concern has been expressed for rural subpopulations whose drinking water may be affected by acid rain. Research is needed to identify those potentially affected groups and to determine the levels of contaminants in drinking water.

4. Man-Made Structures

Acidic precipitation can contribute to the processes of materials erosion. Thus, buildings, roads, paint, sculptures and other man-made structures can be aesthetically and functionally damaged. The dollar costs of these damages to the urban environment are difficult to calculate, however. In 1985, the value of Canadian construction was \$61 billion; \$11 billion of this total was for repairs and maintenance. The question is, what portion of the observed corrosion and deterioration is due to the effect of acid rain? At the present time, no useful estimate can be made. The most that can be said, in advance of the extensive research needed in this area, is that air pollution has an effect on materials deterioration and acid deposition is one component of that complex situation.

F. Areas of Canada Susceptible to Acidic Precipitation

In general, acid rain does not cause significant damage to an ecosystem unless it lowers the pH of that ecosystem. Areas of the country which have a high buffering capacity should not be seriously affected by acidic precipitation because they have the ability to neutralize the acid.

Buffering capacity refers to the ability of a solution to neutralize hydrogen ions with basic or alkaline ions so that there is no net change in pH. Thus, an environment which has a large buffering capacity can neutralize acid rain, rendering it incapable of harming ecosystems. Buffering capacity is related to the amount of calcareous materials (such as limestone) in soils and rocks and dissolved bicarbonate in water. In parts of the country in which non-calcareous rock formations predominate, the environment has little buffering capacity and can consequently neutralize only limited amounts of acidic precipitation. For example, some lakes in the Haliburton-Muskoka region have lost 40 to 75% of their buffering capacity in less than a decade. Once the buffering capacity has been eliminated, acidic precipitation can no longer be neutralized, the pH of the system drops rapidly, and the ecological effects noted earlier begin to appear.

A large portion of eastern Canada particularly is based on granitic and silicious bedrock. This rock is non-calcareous and extensive glaciation has removed most of the younger

calcareous deposits which may have been present prior to the Ice Ages. This has left vast areas impoverished in terms of calcareous deposits, although glacial deposits of calcareous material have produced some areas of overburden which considerably augment buffering capacities. Large areas of Nova Scotia and New Brunswick, almost all of Newfoundland, most of Quebec and large areas of Ontario are particularly susceptible to the deleterious effects of acid rain. Parts of the Northwest Territories, Manitoba and southern British Columbia are also suspected to be susceptible to acidification. It has been estimated that some 43% of Canada's land area is sensitive to acid deposition.

Areas of Canada which are likely to suffer the most damage are located in Ontario, Quebec and Labrador because of the prevailing westerly winds over most of eastern North America. This pattern varies to some extent with season and, in the Great Lakes region, air often flows to the south in the winter and to the north in the summer.

G. Acid Rain Controls

Despite widespread public concern in the early 1980s there were no comprehensive programs for the abatement of acid rain. That situation has now changed quite significantly with the introduction of the Canadian Acid Rain Control Program in 1985, the passage of the *Clean Air Act Amendments* in the U.S. in 1990 and the signing of the Canada-U.S. Air Quality Agreement in March 1991.

1. The Canadian Acid Rain Control Program

In March 1985, Prime Minister Brian Mulroney announced the Canadian Acid Rain Control Program. This program represents a cooperative undertaking by the federal and provincial governments and industry to reduce SO₂ emissions in eastern Canada by 50% by 1994 from an allowable base of 4.516 million tonnes in 1980. The program takes a three-pronged approach consisting of reductions of SO₂ emissions according to set targets and schedules, the development of new cost-effective technologies to reduce emissions, and an extensive research and monitoring program.

The program will cap SO₂ emissions in eastern Canada at 2.3 million tonnes per year by 1994. Current federal-provincial agreements with the seven eastern provinces allocate

individual limits for 1994 SO₂ emissions; these amount to a total of 2.349 million tonnes, leaving only 49,000 tonnes of emission reductions still to be allocated by the Canadian Council of Ministers of the Environment. New agreements, which allocate the remaining reductions and cap SO₂ emissions from the eastern provinces at 2.3 million tonnes/year until the year 2000, are being finalized. New Brunswick, Nova Scotia, Ontario, and Quebec have already signed new agreements. The three western provinces will become part of the program by the year 2000, when the national cap will be set at 3.2 million tonnes. It is unlikely that the national cap will be met by allocating the additional 0.9 million tonnes of SO₂ emissions to the three western provinces. Such an allocation could inhibit industrial expansion in the West and would not be justified on environmental grounds.

The governments of Ontario, Manitoba and Quebec have passed regulations to place legal limits on emissions from large emitters of SO₂, including six non-ferrous metal smelters and Ontario Hydro. New Brunswick Power and Nova Scotia Power Corporation, which are the major emitters of SO₂ in the Atlantic Provinces, have developed control strategies to achieve the required reductions.

The National Air Issues Steering and Coordination Committees have agreed upon a three-year program to look at how to manage SO₂ emissions under the national cap of 3.2 million tonnes, whether to seek a reduction of the national cap and whether to pursue further reductions of SO₂ emissions with the U.S. Recommendations on these issues will be made in 1997.

The 1992 Annual Report on the Federal-Provincial Agreements for the Eastern Canada Acid Rain Program, which contains the most recent provincial estimates, shows that total eastern SO₂ emissions in 1992 were 2,316 kilotonnes, very close to the 1994 target of 2.3 million tonnes. National emissions in 1992 were slightly below the year-2000 cap of 3.2 million tonnes.

The report concludes that, although a substantial proportion of aquatic environments in Ontario, Quebec, Nova Scotia, and Newfoundland are showing indications of recovery from the effects of acid rain and program goals are being met, many acid-sensitive Canadian ecosystems are still being damaged.

In contrast to the success in reducing SO₂ emissions in North America, nitrogen oxide emissions have remained fairly constant. There is serious concern that nitrogen-based acidification in the future might erode the benefits of reduced SO₂ emissions.

2. The U.S. *Clean Air Act Amendments*

On 15 November 1990, President Bush signed Amendments to the *Clean Air Act*. Title IV of the Amendments authorized the Environmental Protection Agency (EPA) to establish an Acid Rain Program, the overall goal of which is to reduce SO₂ and NO_x emissions. The program will primarily affect electric utilities, which account for 70% of sulphur dioxide emissions and 30% of nitrogen oxide emissions in the U.S. The legislation proposes to cut annual emissions of SO₂ and NO_x by 9.1 and 1.8 million tonnes by the year 2000.

The strategy to cut sulphur dioxide emissions will be implemented in two phases. In the first phase, which lasts from 1995 through 1999, 110 coal-burning electric utility plants located in 21 eastern and midwestern states will be regulated. In Phase II, which starts in 2000, smaller and cleaner plants burning coal, oil or gas will also be regulated. All existing units with an output capacity of 25 or more megawatts will be affected. In addition, annual emissions limits on the large coal-burning plants will be tightened.

A key element of the U.S. program is an emissions allowance trading system. This enables the federal government to set the overall limits for emissions but makes use of the market place to find the most efficient means of meeting the limits through the economic incentive of the tradeable allowances. The EPA has estimated that the market-based system will save industry \$1 billion compared to more traditional methods. Even so, it is estimated that the program will cost about \$18 U.S. per person per year once the provisions are fully in place.

The emissions trading system is based on a set of regulations known as the "core rules," which consists of rules on an Allowance System, Permits, Continuous Emissions Monitoring, Excess Emissions and an Administrative Appeals Process. The proposed rules were issued in December 1991. The publication deadline mandated by the *Clean Air Act Amendments* for the final version of the rules was 15 May 1992. The core rules were published in January 1993 and a further rule on Phase II allowances was published in March 1993. The delay in

publishing the final rules should have little effect on scheduled SO₂ reductions, given the strict deadlines imposed by the Act.

3. Canada-U.S. Air Quality Agreement

On 13 March 1991, Prime Minister Mulroney and President Bush signed the Air Quality Agreement between Canada and the United States, which addresses shared concerns about transboundary air pollution. The first air pollution issue the Agreement tackles is acid rain. Sulphur dioxide emissions will be permanently capped in both countries to approximately 13.3 million tonnes by 2010 in the U.S. and 3.2 million tonnes by 2000 in Canada. Precise commitments and schedules are specified in Annex 1 of the Agreement. Other requirements include the scheduled reduction of nitrogen oxide emissions over the next 10 years, tighter emission standards for new motor vehicles, the monitoring of sulphur dioxide and nitrogen oxide emissions, and specific actions to protect both countries' pristine wilderness areas from transboundary air pollution. Annex 2 of the Agreement describes the coordination of research and monitoring activities and the exchange of scientific and technical information which will improve understanding of transboundary air pollution and the ability to control it.

The Agreement established a joint Air Quality Committee to assist with the implementation of the Agreement and to report on progress. The Air Quality Committee held its inaugural meeting on 26 November 1991 in Washington, DC and released its first progress report on 17 June 1992.

The Canada-U.S. Air Quality Committee released its second report in late 1994. The situation reported by the Committee is generally positive. Canada has substantially met its emissions target for eastern Canada two years ahead of schedule and the U.S. has issued all of its major regulations. Water quality monitoring at 111 sites in southeastern Canada shows that 72% of the waters are either improving or have stabilized, 13% are stable with respect to acidity but have increasing sulphate levels, and 15% (mostly in Ontario and Quebec) are continuing to acidify. Scientists predict that parts of Canada will still be acidified after the year 2000; as a result, Canada is now developing a new National Strategy on Acid Rain to protect acid-sensitive areas in the post-2000 period.

In contrast to the largely positive trends on sulphate, survey data from a number of lakes and streams in the Adirondack and Catskill Mountains of New York, the Mid-Appalachian region, Ontario, and Québec show increasing nitrate concentrations. The report suggests that maintenance of existing levels or increases of nitrogen deposition over the long term may eventually undermine the benefits derived from SO₂ control programs.

4. Second International SO₂ Protocol

A second international Protocol to reduce SO₂ emissions was signed in Oslo, Norway, on 14 June 1994. The Protocol, which was negotiated through the United Nations Economic Commission for Europe, commits Canada to continue controlling its sulphur emissions in order to protect human health and the environment; to support the long-term aim of working toward achieving critical loads; to establish a Sulphur Oxide Management Area (SOMA) for southeastern Canada; and to support the establishment of a multinational Implementation Committee to review the implementation of the Protocol and compliance by the Parties.

Unlike the first Protocol, which committed all parties to an across-the-board 30% reduction of SO₂ emissions, the second Protocol sets out sulphur emissions ceilings that vary by country, with decreasing ceilings set for many countries for the years 2000, 2005, and 2010. Canada's national target remains 3,200 kilotonnes for the year 2000. The SOMA will have a ceiling of 1,750 kilotonnes SO₂ for that year.

PARLIAMENTARY ACTION

A. Sub-committee on Acid Rain

The House of Commons Standing Committee on Fisheries and Forestry established a Subcommittee on Acid Rain by Order of Reference of Wednesday, 30 April 1980 to enquire into the costs and effectiveness of finding solutions to the acid rain problem. The Report of the Sub-committee, *STILL WATERS*, was made public on 8 October 1981 and among other things recommended that the *Clean Air Act* be amended to enable the federal government to develop National Emission Standards to cover sources of sulphur dioxide and nitrogen oxides resulting in interprovincial air pollution and acid rain.

The Subcommittee was reappointed in March 1983 following receipt of an Order of Reference by the Standing Committee on 9 March 1983. The Subcommittee's final report on acid rain, *TIME LOST*, was released on 7 June 1984 and contained 16 recommendations. With the tabling of this report, the Subcommittee was dissolved under the terms of its Order of Reference of 9 March 1983.

On 4 June 1985, a Special Committee on Acid Rain was appointed by the House of Commons to "hold hearings to review all aspects of acid rain." The Committee was chaired by Stan Darling, M.P. and had seven members, consisting of five Progressive Conservatives, one Liberal and one NDP.

On 13 February 1986, the Special Committee on Acid Rain tabled its First Report in the House. The Committee stated that it "views the Report (of the Special Envoys on Acid Rain) as having failed to adequately address critical elements in the control of acid rain," principally because the Report asks for more research and does not set targets and dates for emission reductions.

On 29 September 1988, the Committee tabled a report that summarized the activities of the Special Committee on Acid Rain since 1986, discussed the major issues that arose during hearings, and provided an overview of the Canadian position and progress on acid rain.

In June 1991, a new Subcommittee on Acid Rain of the House of Commons Standing Committee on Environment was established, under the Chairmanship of Mr. Stan Darling, M.P. Mr. Darling was previously Chairman of the Special Committee on Acid Rain. The agenda for the Subcommittee included an evaluation of the status of the Canadian Acid Rain Control Program, and other aspects of the acid rain problem. The Subcommittee tabled its report "From Words to Action" in December 1992.

B. *Clean Air Act*

On 16 December 1980, the House of Commons passed Bill C-51, An Act to amend the Clean Air Act. The amendment empowered the Minister of Environment Canada to recommend appropriate emission standards to control air pollutants from Canada which "may

reasonably be expected to constitute a significant danger to the health, safety or welfare of persons in a country other than Canada." This amendment harmonized Canada's *Clean Air Act* with the comparable U.S. law, which had a similar provision with regard to transboundary air pollution. The *Clean Air Act* is now incorporated into the *Canadian Environmental Protection Act* (CEPA).

CHRONOLOGY

- 1950s - The acidification of lakes was described in Canada for the first time in the Killarney area near Sudbury in Ontario.
- 1976 - The Canadian Network for Sampling Precipitation (CANSAP) began monitoring rainfall in 1976.
- 9-11 July 1979 - The Great Lakes Science Advisory Board warned that aquatic and terrestrial ecosystems in the Great Lakes Basin were being threatened by acid rain.
- 15 October 1979 - The Governments of Canada and the United States jointly released the first report of the United States-Canada Research Consultation Group (RCG) on the Long-Range Transport of Air Pollutants (LRTAP). The report recognized acidic precipitation as a problem of great common concern.
- 13 November 1979 - Canada, the United States, and the other 32 member nations of the Economic Commission for Europe signed the international "Convention on Long-Range Transboundary Air Pollution (LRTAP)". The signatories agreed to exchange data on sulphur dioxide emissions and on long-range industrial policies likely to affect these emissions. The Convention lacks an enforcement mechanism and does not compel the signatories to effect abatement procedures.
- 5 August 1980 - Canada and the United States signed a Memorandum of Intent Concerning Transboundary Air Pollution as a preliminary step in the development of a bilateral cooperative agreement on air quality which would deal effectively with transboundary air pollution.

- 15 June 1982 - Acid rain negotiations under the Memorandum of Intent collapsed.
- February 1983 - The final reports of the Canada-United States Work Groups established in August 1980 under the Memorandum of Intent were released. The Canadian team maintained its position that the acceptable level of sulphate (from sulphur dioxide pollution) is 20 kilograms per hectare per year, and can only be achieved by halving current emission levels.
- June 1983 - A series of reports on acid rain from groups in the United States was issued and, in the main, confirmed the principal points raised earlier by the Canadian government with respect to the threat posed by acidic deposition and the link to industrial SO₂ emissions. The U.S. groups included the National Academy of Sciences and the President's Office of Science and Technology Policy.
- 5 February 1985 - The federal government and the seven provinces east of Saskatchewan agreed to reduce annual emissions of SO₂ by 1.89 million tonnes (from a total of 4.5 million tonnes), a 42% reduction, by 1994.
- 6 March 1985 - The federal government stated it would contribute up to \$150 million over 10 years to help modernize the smelting industry to reduce SO₂ emissions. An Environment Canada official estimated that the smelting industry could need up to \$750 million in capital improvements to reduce SO₂ emissions sufficiently to meet the government's stated goals for 1994.
- July 1985 - Representatives from 21 countries signed a protocol in Helsinki calling for a 30% reduction in emissions or transboundary movement of sulphur dioxide by 1993 from U.N. Economic Commission for Europe (ECE) Convention on long-range transboundary air pollution. Among the parties to the agreement are Canada, West Germany and Sweden. The United States and the United Kingdom declined to sign the protocol.
- 17 December 1985 - The Ontario Government announced an \$85-million acid rain program, named "Countdown Acid Rain", to cut SO₂ emissions in the province by 1994 to 665,000 tonnes from the 1980 level of 1,993,000 tonnes, a reduction of 67%. Major reductions would be effected at Inco's Sudbury smelter, the Falconbridge

smelter near Sudbury, Algoma Steel's iron ore plant at Wawa, and at Ontario Hydro's coal-fired power stations.

- 9 January 1986 - United States and Canadian envoys, Drew Lewis and William Davis, appointed in March 1985, released their report on acid rain. The report did not recommend a cleanup program; instead, it recommended an expenditure of \$5 billion (U.S.) over five years to research more efficient technologies by which U.S. power plants could burn coal, a major source of Canada's acid rain. Critics of the report stated that suitable technologies already exist and that the funds should be directed towards controls.
- 14 March 1986 - The National Research Council of the U.S. National Academy of Sciences released a study by U.S. and Canadian scientists which concluded that there is a causal relationship in eastern North America between SO₂ emissions and the wet deposition of sulphate and the progressive acidification of lakes and streams.
- 19 March 1986 - President Reagan gave his full endorsement to the Report of the Special Envoys on Acid Rain at the conclusion of his summit meeting in Washington with Prime Minister Mulroney.
- 26 March 1986 - Transport Canada published in the *Canada Gazette Part II* (Vol. 120, No. 8) an amendment to the Motor Vehicle Safety Regulations respecting emission standards for light- and heavy-duty motor vehicles, including automobiles, light-duty trucks, and heavy-duty vehicles. More stringent emission standards for cars and light-duty trucks would become effective on 1 September 1987, for the 1988 model year. They set lower limits for NO_x, hydrocarbons and carbon monoxide. Environment Canada estimated that the new standards would bring about a 45% reduction in automobile pollution by the year 2000.
- 10 March 1987 - Environment Minister Thomas McMillan signed an agreement with Ontario on acid rain control, formalizing a February 1985 agreement to reduce eastern Canada's sulphur dioxide emissions by 50% by 1994. Prince Edward Island and Newfoundland signed similar agreements on 9 March 1987. Negotiations were continuing with New Brunswick and Nova Scotia.
- 20 March 1987 - The federal and Quebec Governments signed an acid rain control agreement. Noranda Inc. was to reduce sulphur dioxide

emissions from its Horne Smelter in Rouyn-Noranda by 50% when a new sulphuric acid plant came into operation in 1989. The company would be assisted by more than \$83 million in loans from the two governments.

- 10 April 1987 - Environment Minister Thomas McMillan and Manitoba's Environment Minister, Gerard Lecuyer, signed an agreement to reduce the province's SO₂ emissions by 25% from allowable 1980 levels by 1994. The agreement included an offer by the federal government to contribute \$20 million to the Hudson Bay Mining and Smelting Company smelter at Flin Flon to help achieve emission reductions.
- May 1987 - Ontario Environment Minister James Bradley announced in the legislature that the emissions banking provision for Ontario Hydro would be deleted from provincial regulations. The announcement followed a unanimous recommendation from the legislature's Select Committee on the Environment on 11 May.
- 17 September 1987 - The United States National Acid Precipitation Assessment Program (NAPAP) presented its interim report. The report's Executive Summary tended to downplay the seriousness of acid rain in the United States and the E.P.A. said that the evidence presented in the report indicated that increased acid rain controls were not necessary. The Canadian Environment Minister described the NAPAP report as "flawed, incomplete and misleading" and "out of step with prevailing scientific judgment and expert opinion". Other critics in the U.S.A. and Canada said the report's Executive Summary was a politically biased document that did not fairly represent the scientific facts. A senior U.S. State Department official said that the NAPAP report supported Administration policies on acid rain.
- 8 October 1987 - The New Brunswick government signed a written agreement with the federal government to reduce SO₂ emissions in 1994 by 16%, from 1980 allowable levels. The agreement was signed by Premier Richard Hatfield, who was defeated in a general election five days later.
- November 1987 - After a meeting in Geneva of the United Nations Economic Commission for Europe (ECE), held to discuss a draft protocol for NO_x emissions, Canadian negotiators received negative publicity in the media for an apparent refusal to support an across-the-board 30% reduction. In fact, these discussions were

at an early stage and Canada was proposing to link nitrogen deposition to environmental consequences. Also, the deposition of nitrogen compounds in many areas in Europe is six to ten times what it is in Canada and, therefore, a percentage reduction in NO_x emissions appropriate for Europe is not necessarily appropriate for Canada.

- 12 February 1988 - The federal and Nova Scotia governments signed an agreement respecting an acid rain reduction program. The purpose of the agreement was to reduce wet sulphate deposition in Eastern Canada in accordance with the Federal/Provincial Environment Ministers' Agreement of 5 February 1985. In a parallel action, taken to assist the provincial government financially, the federal government reduced the price of coal purchased by the province from the Cape Breton Development Corporation to fuel its power plants. Nova Scotia was now committed to reducing its annual SO₂ emissions to 204,000 tonnes before 31 December 1994, the date on which the agreement expires.
- 16 February 1988 - Environment Canada released a "National Sensitivity Assessment" map showing that 46% of Canada has a low ability to neutralize acidic precipitation. All regions of Canada have acid-sensitive areas but Quebec is the most sensitive, with 82% of its area having the lowest rating for neutralizing capacity. Newfoundland, Nova Scotia, and Ontario's Muskoka and Haliburton regions are also highly sensitive.
- 29 March 1988 - Ontario Hydro gave an environmental assessment study to the provincial environment minister which estimated the capital cost of retrofitting its three major coal-fired generating plants with scrubbers at \$3 billion. The three plants are Lambton near Sarnia, Lakeview in and Nanticoke on Lake Erie southeast of Hamilton; they account for 93% of Ontario Hydro's coal-fired generation and are designed to burn medium-sulphur coals from the United States. If power demand is higher than anticipated during the 1990s, however, the capital cost could rise to \$5.5 billion because as many as 20, rather than eight, scrubbers would be required to effect the necessary reduction in emissions.
- 10 February 1989 - During his visit to Ottawa, President Bush stated his "determination to move forward with setting limits (on acid rain precursor pollutants), with (domestic) legislation and then moving to a discussion with Canada leading to an accord that I think will be beneficial for both countries." There was general agreement

among observers that a Canada-U.S. accord on acid rain would have to follow domestic U.S. legislation.

- 20 April 1989 - The Ministers of Environment and Transport announced that the federal government was starting an assessment of environment and health benefits, socio-economic impacts, and technical feasibility of new emission controls for all internal combustion engines. The objective of this initiative is "to put in place, within five years, the most stringent regulations that technology will allow to control emissions (including NO_x and volatile organic compounds) from internal combustion engines that burn fossil fuels." New regulations could be in place within 48 months.
- 12 June 1989 - In Bill H.R. 3030, President Bush proposed amendments to the U.S. *Clean Air Act* which would be "a comprehensive program to provide clean air for all Americans." The proposals would bring about a reduction of SO₂ emissions of 10 million tons from 1980 base levels, by the year 2000. NO_x levels would be frozen at about 1987 levels. Canadian officials generally welcomed the proposals as meeting Canada's environmental needs; they also would form the basis for eventual negotiations on a bilateral air quality agreement.
- 19 October 1989 - The Canadian Council of Ministers of the Environment announced that the federal ministers of Environment and Transport would, within the next month, publish notice of their intent to issue a regulation aimed at achieving the proposed California standards for hydrocarbons (0.25 grams per mile), carbon monoxide (3.4 grams per mile) and nitrogen oxides (0.4 grams per mile) for the 1994 model-year cars. Also, provincial Ministers would undertake to implement by 1992 vehicle inspection and maintenance programs in provinces with ozone problems.
- 23 May 1990 - The United States House of Representatives passed its version of amendments to the *Clean Air Act*, H.R. 3030. The Senate passed a similar bill, S. 1630, in April. The legislation was expected to obtain presidential signature before the 1990 mid-term elections.
- 16 July 1990 - The Minister of Environment Canada, Robert de Cotret, and the Administrator of the Environmental Protection Agency, William Reilly, announced that a Canada-U.S. Air Quality Agreement would be developed to manage a comprehensive range of

transboundary pollutants. Among its goals, the Agreement would give priority to emissions of SO₂ and NO_x, and establish a means for impartial oversight and dispute settlement.

- 28 August 1990 - Negotiations to develop a Canada-U.S. Air Quality Agreement commenced in Ottawa.
- October 1990 - On 20 October, the United States Senate passed the bill amending the *Clean Air Act* by an 89-10 margin. The House of Representatives passed the bill on 26 October by a 401-25 vote.
- 15 November 1990 - President Bush signed the bill amending the *Clean Air Act* into law. The new legislation mandated significant reductions in sulphur dioxide and nitrogen oxides and, by extension, in acid rain.
- 13 March 1991 - President Bush and Prime Minister Mulroney signed the Canada-United States Air Quality Agreement in Ottawa. The bilateral accord built on the U.S. *Clean Air Act* of 1990 and the Canadian Acid Rain Control Program of 1985. It committed the two governments to a series of targets and schedules for the control of transboundary pollutants. In addition to the control of acid rain precursors, the accord provided for the prevention of significant air quality deterioration from transboundary air pollution, and protection of visibility, particularly for parks and wilderness areas.
- 23 September 1991 - Canadian Environment Minister Jean Charest announced \$30 million in Green Plan funds to support Canada's acid rain control program. The funds were to be used to implement the federal-provincial cap on SO₂ emissions in Canada, to verify the effectiveness of the Canada-U.S. Air Quality Agreement and to support scientific efforts to improve understanding of the effects of acid rain.

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